



PUTTING RESEARCH TO WORK

BRIEF

Factoring Air Temperature into Asphalt Pavement Design

Wisconsin DOT bases its design practices for asphalt pavement on the 1972 AASHTO pavement design guidelines and their 1986 and 1993 revisions. These procedures use the structural number concept, in which designers assign each pavement layer a number determined by the type of material and its thickness. The sum of all layers' structural numbers represents the pavement's overall strength.

Although WisDOT's design procedures have evolved to incorporate more sophisticated volumetric inputs, the department's methods are essentially empirical, and lack the benefit of the current body of knowledge on the mechanistic behavior of hot-mix asphalt constituents.

What's the Problem?

WisDOT and other agencies around the country are currently reviewing preliminary mechanistic-empirical guidelines that are expected to replace current pavement design procedures in the next few years. These sophisticated ME directives include design inputs for mixture types, aggregates, binders, mix temperature, and other factors.

However, for these guidelines to be effective in Wisconsin, WisDOT must develop inputs that reflect the mechanical properties of materials that will be used in asphalt pavement construction here. One critical structural characteristic, modulus—which can be loosely thought of as a material's reactivity to loading force—varies with climatic changes at the pavement site. To ensure design reliability, WisDOT needs a method for predicting modulus based on prevailing air and/or mixture temperatures.

Research Objectives

The central objective of this study was to develop modulus-to-temperature relations for HMA mixtures used in Wisconsin. Dynamic modulus (a material's ability to spring back from nonstatic or recurring loading stress) is preferred as a design input in the new ME design guidelines. However, since procedures for determining dynamic modulus remain in development, the commonly used measurement of resilient modulus (a material's ability to spring back from static or incidental loading stress) was deemed to offer a reasonable approximation of the dynamic modulus input until the ME guidelines can be thoroughly vetted.

Methodology

This research was divided into three phases:

- **Literature review.** Researchers reviewed documented methods for estimating or back-calculating resilient modulus of HMA layers from nondestructive test data.
- **Field study.** Investigators studied four HMA mixture types, in combination with three nominal maximum aggregate sizes, two coarse aggregate types and four binder types. They conducted deflection testing in the field, then lab-tested cores from seven pavement sites to correlate mix temperature with asphalt layer modulus.
- **Data analysis and guideline development.** Researchers used the collected deflection data to back-calculate HMA layer moduli for the mix temperatures tested. They used these results and lab test results to establish modulus-to-temperature relations for each mix type tested. They then developed guidelines for the use of these relationships in a mechanistic pavement design process.

Results

Researchers developed a simple procedure for estimating in-place resilient modulus of HMA based on surface deflection data that is commonly collected on WisDOT paving projects. Investigators also pro-

Investigator



"We know that modulus changes with temperature. But for the new mechanistic design procedures we need to have sophisticated data inputs for this relationship. This study helps us develop those."

—James Croveti

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Project Manager



“In mechanistic-empirical design we will have a more reliable method for predicting pavement performance. This study takes us a step in that direction by correlating layer behavior with simple material properties.”

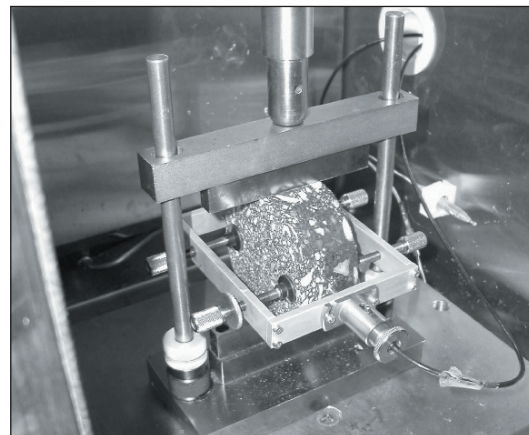
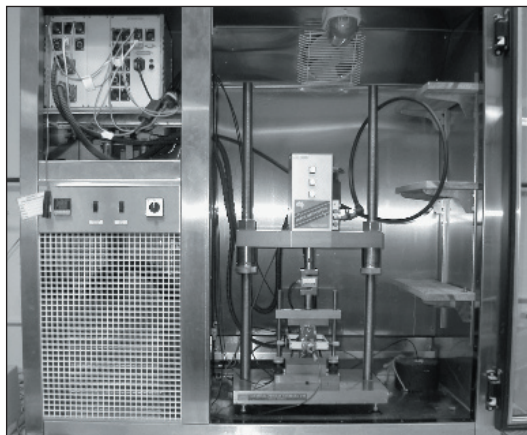
—Len Makowski

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Using equipment already in use at WisDOT, such as this indirect tensile test equipment, researchers developed models for predicting the resilient modulus of asphalt pavement according to air temperatures at pavement sites.

duced regression equations that use lab-derived resilient modulus data to estimate resilient modulus at specific temperatures in the field based on fines content, air void content and binder content.

This research also yielded a process for using climatic data—mean monthly air temperature—to develop estimated HMA resilient modulus values for each month for a given region. These monthly estimates can be used as inputs in a mechanistic performance analysis.

Detailed results and conclusions included:

- Researchers developed both general and mixture-specific regression equations. The mixture-specific models are based on readily obtainable project data, and effectively predict HMA moduli in correlation with temperature variation.
- Modulus-to-temperature relations were affected by all mixture properties investigated. Generally, HMA resilient modulus increases at all temperatures as fines increase, binder percentage decreases, and/or the percentage of air voids decreases.
- Although estimations of HMA resilient modulus from deflection data correlate reasonably well with laboratory measurements, variation in thickness and stiffness of lower pavement layers can significantly impact analysis. Care must be exercised if deflection data is the sole source of mechanistic information in a paving project.

Implementation and Benefits

The procedures developed in this research bridge the significant gap between WisDOT's current design and performance prediction practices and the ME methods that will be adopted in the next few years. With existing equipment and commonly collected surface deflection data, WisDOT pavement designers can use the methods developed in this study to predict mechanistic performance more accurately than current methods allow.

Further Research

Since dynamic modulus will be used as an input in the new ME design guidelines, a related study (WisDOT Project 0092-04-07, “Testing Wisconsin Asphalt Mixtures for AASHTO 2002 Mechanistic Design Procedure”) is currently in progress to develop procedures for determining and using dynamic modulus in design and performance prediction.

This brief summarizes Project 0092-03-14, “Development of Modulus-to-Temperature Relations for HMA Mixtures in Wisconsin,” produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research, Development & Technology Transfer Program, 4802 Sheboygan Ave., Madison, WI 53707.

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